

Review

Balancing Gains and Losses—A Research Note on Tradeoffs in the Case of Non-Alcoholic Wines in Germany

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Abstract: Non-alcoholic alternatives are gaining growing significance within the German beverage sector. In this context, the German wine industry is increasingly focusing on non-alcoholic wines, whose market has developed dynamically in recent years. While the technologies used, the sensory characteristics and the marketing of the products are frequently addressed in the literature, the consideration of sustainability impacts has so far been largely neglected. This applies in particular to the view of all three dimensions of sustainability. These are examined more closely in this review with regard to tradeoffs, which indicate that positive aspects in one dimension go hand in hand with a loss in the other. It can be shown that tradeoffs in the production and marketing of non-alcoholic wines arise both within and between the three sustainability dimensions. Exemplary of this is the increased use of resources in the course of alcohol removal. At the same time, an emerging market segment holds positive aspects from an economic perspective. Ultimately, the consideration of social sustainability is marked by the health science and political debate around the reduction in alcohol consumption and the simultaneous increase in the consumption of non-alcoholic alternatives.

Keywords: non-alcoholic wine; dealcoholization; beverages; tradeoff



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1. Introduction

The case of non-alcoholic wine has one of its roots in the recent discourse surrounding the negative effects of alcohol consumption on health and society. According to the World Health Organization (WHO), there is a direct correlation between alcohol consumption and increased risks of liver diseases, various cancers, the accelerated spread of infectious diseases such as HIV and mental health disorders. Additionally, there is a consistent emphasis on the link between alcohol consumption and traffic accidents as well as domestic violence [1,2]. The associated negative externalities reinforce the call for stronger alcohol policies [3].

From the perspective of social sustainability, the steady increase in the consumption of non-alcoholic alternatives and the decline in alcohol consumption represent a positive development. The per capita consumption of alcoholic beverages including beer, wine and spirits in Germany has fallen from 137.8 to 120.1 L since 2010 [4]. In contrast, non-alcoholic beer has seen a notable increase in consumption from 2.95 liters to 4.69 liters per capita between 2014 and 2022 [5]. Detailed consumption data are not yet available for non-alcoholic spirits and wine. However, non-alcoholic wines emerged as the fastest-growing category in the German wine market in 2022. Despite this, these products occupy a niche position with still wines capturing less than one percent of the market and non-alcoholic sparkling wines holding around five percent [6,7].

While these developments suggest positive outcomes from a social perspective, examining the ecological dimension in the field of non-alcoholic wines presents a different scenario: To produce non-alcoholic wines, the alcohol is removed from already-fermented wine using a dealcoholization process, such as vacuum distillation [8]. The utilization of

an additional process implies increased resource input in the production of non-alcoholic wines. These observations already hint at a balancing act concerning sustainability: alcohol is removed, while additional resources are used.

The examination of sustainability impacts in the field of non-alcoholic wines has received little attention so far. Furthermore, the interaction between the sustainability dimensions highlights the challenge of concurrently achieving sustainability goals, often entailing a tradeoff between gains and losses, as depicted in Figure 1. The aforementioned considerations in the area of non-alcoholic wine are a fitting example here: while the social dimension is associated with positive aspects, the ecological dimension is negatively affected. Tradeoffs can be defined as “compromise situations when a sacrifice is made in one area to obtain benefits in another” [9].



Figure 1. Balance between gains and losses in sustainability.

The inclusion of economic considerations, therefore, presents a more nuanced perspective on the case of non-alcoholic wine: the growing market significance indicates the emergence of a new sector within the wine industry, underscoring its relevance for the entire sector from an economic standpoint.

In essence, the market for non-alcoholic wines serves as a particularly suitable case in which to consider tradeoff situations. Thus, this review attempts to shed more light on the tensions within and between the individual dimensions in the field of non-alcoholic wines. These tensions represent a crucial area of research concerning the production, marketing and long-term development of the category.

The remainder of this narrative review is structured around the three pillars of sustainability, each linked to non-alcoholic wines in Sections 2–4. A literature review focusing on the years 2000 to 2023 was conducted using databases such as Scopus, JSTOR and Scholar and in digital libraries of German universities, with keywords including non-alcoholic wine, sustainability and dealcoholization. Section 2 outlines the fundamental options for alcohol reduction and removal, examining them from an ecological perspective. Section 3 delves into the market development of non-alcoholic wines to date, concentrating on economic aspects. Section 4 explores the social consequences associated with alcohol consumption in order to provide a better understanding of the increased consumption of non-alcoholic alternatives. Each section concludes with the presentation of potential tradeoffs, which are subsequently discussed in Section 5.

2. Ecological Sustainability in the Field of Non-Alcoholic Wines

2.1. Processes to Reduce and Remove the Alcohol Content of Wine

The technologies and procedures used for the reduction in and removal of ethanol are extensively discussed in the literature [8,10–12]. One of the primary focuses is on the influence of dealcoholization on the sensory profile of the products, which often deviates significantly from that of the “original” wine [13]. Selecting the most efficient strategy to produce wine with reduced alcohol concentration requires a balance between ethanol removal, energy demand and potential effects on wine composition and sensory attributes [14]. Hence, it is somewhat surprising that the environmental sustainability aspect of non-alcoholic wines has hardly been investigated so far.

The methods for reducing alcohol content in wine can be distinguished between two different approaches:

- Viticultural, Oenological and Microbiological Approaches;
- Physical Technologies.

These approaches vary in their influence on wine composition and ecological factors, as well as in the extent of alcohol removal.

2.2. Viticultural, Oenological and Microbiological Approaches

Viticultural and pre-fermentation methods aim at reducing fermentable sugars. This can be achieved by planting grape varieties or clones that produce less sugar, harvesting grapes earlier, or technically removing the sugar [10,11]. Earlier harvesting has no impact on the ecological sustainability of the product, whereas the technical removal of sugar consumes energy. Sugar can be removed from the must through nano- or ultrafiltration. However, compared to other possibilities of alcohol reduction, sugar removal involves a relatively large loss of volume. For the reduction of 1 vol% (17 g/L sugar), the initial volume decreases by 7% [10].

A promising approach to lowering the alcohol content of wines is the utilization of Non-*Saccaromyces* (N.S.) yeast species [15,16]. A pure use of Non-*Saccaromyces* yeast is not feasible as there must always be a simultaneous or temporally deviating inoculation of *Saccaromyces* and N.S. [15]. Contreras et al. [15] were able to produce wines with 0.9 and 1.6 vol% less alcohol than wines fermented solely with *Saccaromyces cerevisiae* by using the yeast *Metschnikowia pulcherrima* AWRI1149 in combination with *Saccaromyces cerevisiae*.

Morales et al. [17] demonstrated that aerobic fermentation results in lower alcohol content. This effect was observed with both *Saccharomyces* and mixed cultures and exhibited a strong negative correlation. The reduction was stronger in the mixed cultures compared to pure fermentation with *Saccharomyces*, with alcohol content being reduced by 2.9 to 3.7 vol%. However, aerobic fermentation resulted in increased levels of acetic acid.

Non-*Saccaromyces* yeast naturally occurs on berry skin and dominates the early phase of fermentation [15,16], before *Saccaromyces cerevisiae* prevails. The flavor impact of N.S. on the wine varies depending on the type and strain. However, the flavor influence differs significantly from *S. cerevisiae* [16].

2.3. Physical Technologies

While the methods discussed previously are primarily associated with reducing the alcohol content of wine, the only feasible approach for producing non-alcoholic wine involves employing physical processes. This is due to the fact that they allow for a reduction in alcohol content by more than 4 vol% [14]. The physical processes for the dealcoholization of wine can be further categorized into thermal and membrane processes. The most common methods include spinning cone column (SCC), reverse osmosis and nanofiltration [18]. These physical methods also differ from each other in terms of energy and water consumption.

Vacuum rectification is based on the principle of distillation, where liquids are evaporated. The separation process relies on the different volatilities of the liquids [10]. At normal pressure, alcohol evaporates at approximately 78 °C. To prevent negative changes to the wine's aroma components at such high temperatures, the pressure inside the plant is reduced to between 0.05 and 0.2 bar for the production of non-alcoholic wines. This enables distillation to occur within a temperature range from 20 to 30 °C [19].

The spinning cone column (SCC) is a special form of vacuum rectification [10]. It consists of vertical cones rotating at up to 350 revolutions per minute (rpm), with static cones attached between them. The feed is fed to the top of the column into the first spinning cone [11]. The rotation creates a film of liquid, approximately 1 mm thick on average, facilitating efficient contact between vapor and liquid [10]. The volatile substances pass from the liquid to the gaseous phase and are subsequently condensed. Negative pressure can reduce the process temperature to about 30 °C [11,20]. Additionally, the process can be assisted by a stripping gas [20], using either nitrogen or previously separated non-condensed wine ingredients [11]. The dealcoholization of wine with SCC involves a

two-stage process [11,19]: first, the volatile aromatics are separated at a low temperature (approx. 28 °C), followed by alcohol separation at a higher temperature (approx. 38 °C) [11]. This is then followed by a rebinding with the aroma feed.

This process alters the sensory profile due to a loss of certain characteristics like body and fullness [13]. Additionally, acidity concentrates during the process, necessitating the addition of sugar in the form of grape must, concentrated grape must or rectified grape must to balance out the sensory profile. Consequently, a dry-tasting non-alcoholic wine may therefore contain significantly more sugar than an alcoholic wine with a similar flavor profile.

Osmotic distillation, also known as evaporative pertraction, is a promising technology for wine dealcoholization. Compared to reverse osmosis or SCC, this membrane process offers lower energy consumption [18] and less impact on wine aroma [21]. This is achievable due to the significantly lower pressure and the process being carried out at ambient temperature [21,22]. Moreover, the purchase costs of the plants are low (starting from approximately EUR 7000), and the process is easy to carry out and requires minimal supervision. The systems are compact and portable, making them suitable for use by small wineries or across companies, offering an advantage especially over SCC [10]. However, osmotic distillation has disadvantages, including longer extraction times for equivalent alcohol removal [11] and increased water consumption.

Margallo et al. [18] conducted a Life Cycle Assessment comparing spinning cone columns, evaporative pertraction and reverse osmosis. In their study, evaporative pertraction emerged as the most environmentally favorable technology. However, when considering the energy recovery of the wastewater from SCC, it became the preferred technology. Wastewater valorization is only suitable for SCC due to the high alcohol content of the wastewater. An energetic improvement of the process could be achieved by concentrating the permeate with the help of distillation or pervaporation for subsequent utilization, such as bioethanol production [21]. The impact of valorization on the overall sustainability of the process still requires further investigation. It should be noted, however, that Margallo et al. [18] focused on partial dealcoholization. When dealing with higher alcohol contents, energy requirements increase, potentially altering the differences between the individual techniques. Still, the study shows that the dealcoholization of wine is generally associated with an increased carbon footprint due to the additional alcohol removal process. This aspect is particularly significant as dealcoholization also leads to a loss of volume [7]. However, a comprehensive review of the literature did not provide more precise data on the carbon footprint of complete dealcoholization.

2.4. Substitutes for Non-Alcoholic Wine

Wine is not the sole product derived from grapevine cultivation. Non-alcoholic beverages can also be produced from dried grape residues or vine leaves. This allows for the valorization of grapevine by-products, which are normally considered waste [23]. Vine leaves are rich in polyphenols, with their content strongly influenced by the timing of leaf harvest [24]. The production of drinks from leaves or grape residues presents a profitable and environmentally friendly way to valorize waste products [23].

2.5. Tradeoffs in Ecological Sustainability within the Field of Non-Alcoholic Wines

This section illustrated the availability of both technical and non-technical approaches for producing alcohol-reduced wines. Non-technical methods, such as utilizing *Non-Saccharomyces*, do not compromise the environmental sustainability of wine production. Conversely, technical processes, such as sugar removal, require energy in the form of electricity, thus contributing negatively to the CO₂ footprint.

An important aspect concerning the environmental sustainability classification of non-alcoholic wine is physical alcohol reduction. While membrane processes consume less energy compared to thermal methods, techniques like osmotic distillation demand water, raising environmental concerns. Moreover, all physical alcohol reduction methods

involve additional processing steps. Consequently, depending on their energy requirements and consumption of other inputs (e.g., water), they may result in a larger CO₂ footprint than conventional wine production. This emphasizes the tradeoff between environmental sustainability and the removal of alcohol, which entails increased energy and resource usage.

3. Economic Sustainability in Non-Alcoholic Wines

3.1. Historical Market Development of Non-Alcoholic Wines

In the context of increasing health awareness, stronger regulatory efforts and the associated decrease in wine consumption over recent years [25,26], the German wine industry is increasingly focusing on non-alcoholic wines. However, non-alcoholic wines have been produced for over 100 years. Broadly, three stages in the development of the products can be identified in Germany: The first process for wine dealcoholization was invented by the German winemaker Carl Jung and patented in 1907. This development coincided with a period when the harmful effects of alcohol consumption were increasingly debated in society [27]. In the German Empire, “temperance associations” and “temperance societies” shaped the critical discourse on alcohol. Therefore, it is not surprising that the development of vacuum distillation for wine falls precisely into this period. However, the products did not achieve significant market relevance during that time, partly due to the lack of a legal framework for non-alcoholic wines.

A second stage commenced towards the late 1980s as a response to emerging health trends, exemplified by the “light wave”. By the early 1990s, there was a notable increase in non-alcoholic wine production in Germany: according to Hieronimi [28], production figures rose from 3.5 million bottles of non-alcoholic wine and sparkling wine in 1991, to approximately 4.3 million in 1992 and around 6.1 million in 1993. However, production stagnated in the following years. Only in the last five years has a dynamic development emerged, affecting not only alcohol-free wines, but alcohol-free alternatives in general. On the one hand, the trend can be attributed to increasing changes in the political framework. For instance, several European countries have adjusted the taxation and pricing of alcoholic beverages in recent years. More significant in the comparatively liberal German alcohol market, however, are developments in the social sphere: young people in particular are consuming fewer alcoholic beverages. Social trends such as Dry January and Sober October are enjoying growing popularity, and an abstinent lifestyle is increasingly being perceived as desirable.

3.2. Current Market Development of Non-Alcoholic Wines

Currently, the market share of non-alcoholic sparkling wines in Germany is estimated at around five percent, with that of still wines at just under one percent [6].

Despite their low relevance in the overall German wine market, non-alcoholic still wines especially are experiencing dynamic growth, with a compound annual growth rate of nine percent for the period between 2021 and 2025. Germany stands out as the largest market for non-alcoholic wines internationally [29].

These developments are accompanied by an increasing variety of products. In addition to the large German wine and sparkling wine producers such as Rotkäppchen-Mumm and Henkell-Freixenet, cooperatives, wineries and start-ups are venturing into the non-alcoholic wines and sparkling wine sector. A recent tasting of non-alcoholic wines conducted by the trade journal *Weinwirtschaft* demonstrated a significant increase in product diversity, with the number of products tasted rising from 20 in 2011 to 247 in 2022.

Despite the higher production costs compared to wines containing alcohol due to the additional dealcoholization process, non-alcoholic wines are primarily positioned in a price segment below EUR 5 per bottle. Large companies, in particular, are focusing on expanding their product ranges by introducing alcohol-free products under their existing brands.

The expansion of production also necessitates an expansion of dealcoholization capacity. In Germany, this is mainly carried out by five contract service providers, each with their

own approach to integrating dealcoholization into their operations [30]. Some specialize exclusively in this refinement step, while others offer it alongside their main business in wine production.

3.3. Tradeoffs in Economic Sustainability within the Field of Non-Alcoholic Wines

In the market of non-alcoholic wines, three important developments can be observed: production is steadily expanding, the variety of different products is steadily increasing and product quality is gradually improving. This sector, which has existed for a long time and was once marginal, is gaining new momentum, even though the market share is relatively low.

Concerning the long-term development of non-alcoholic wines, making concrete statements is challenging due to constant changes in the legal framework. For instance, the current ban on the production of non-alcoholic organic wines in the European Union poses a legal obstacle, as dealcoholization as a permissible oenological process has not been included in the legislation for organic products (EU 848/2018) [31].

Additionally, it remains uncertain to what extent retail will continue to include non-alcoholic products on their wine shelves. Alternatively, in the long run, there could be a tradeoff between alcoholic and non-alcoholic products if retailers choose to replace existing wine listings with non-alcoholic alternatives. This second aspect is particularly important, considering that overall beverage consumption in Germany has not changed significantly.

Overall, the observations indicate a tradeoff from an economic perspective: Alcoholic wines are losing market share, while non-alcoholic alternatives are gaining importance. Non-alcoholic wines could potentially help to compensate for losses from the alcoholic sector. However, if wine consumption stagnates, a rivalry between the two categories could emerge in the long term. Therefore, a more in-depth analysis is needed to determine the extent to which this tradeoff contributes to the positive or negative development of the wine and beverage sector from an economic standpoint.

4. Social Sustainability in Non-Alcoholic Wines

4.1. Social Aspects of Alcohol Consumption

As part of our daily diet, beverages play a central role in social life. Negative influences can be caused by harmful ingredients and consumption patterns. The scientific evaluation of both alcoholic and non-alcoholic beverages has therefore been highly relevant for decades. Since the production of non-alcoholic wines involves the removal of ethanol, the social consequences of alcohol consumption will be given special attention in the following section in order to discuss the social aspects of increasing consumption of non-alcoholic alternatives.

According to the World Health Organization, the global per capita consumption of pure alcohol was estimated at 6.2 L in 2018 [2,32]. Considering the overall consumption level, the WHO consistently highlights various health risks of alcohol consumption. These include serious diseases of the liver, ranging from fibrosis and cirrhosis to hepatocellular carcinomas [33,34]. In general, ethanol consumption is increasingly associated with various types of cancer, such as oral cavity, larynx, hypopharynx, rectum, colon and female breast cancer [35]. Additionally, the danger of a faster spread of infectious diseases such as HIV as well as mental diseases is repeatedly pointed out. Moreover, alcohol consumption is linked to societal issues such as traffic accidents as well as public and domestic violence [2,36,37].

The consumption of alcoholic drinks is thus linked to considerable societal harm and an increased economic burden. A decade ago, alcohol was categorized as an “unhealthy commodity”, akin to processed foods and tobacco, and was recognized as a major risk factor for chronic noncommunicable diseases [38]. As early as 1983, the World Health Assembly identified alcohol consumption and its repercussions as a significant global health issue [39]. In 2010, the “Global Strategy to Reduce the Harmful Use of Alcohol” was introduced, outlining measures to diminish worldwide alcohol consumption [40]. During the 75th World Health Assembly in late May 2022, representatives endorsed the “Global

Action Plan 2022–2030 to strengthen implementation of the Global Strategy to Reduce the Harmful Use of Alcohol” [41]. The World Health Organization consistently emphasizes three policy domains referred to as the “Three Best Buys” due to their straightforward political applicability and notable efficacy: (1) bans on advertising, which should apply to various forms of media, (2) tax increases combined with measures to curb tax avoidance and (3) restrictions on the availability of alcoholic beverages, e.g., by adjusting sales hours [42]. In Europe, the debate has gained significant momentum in the context of the European plan for “Beating Cancer”. The proposals introduced in this plan are strongly oriented towards the WHO’s Best Buys [43–45].

The recent decisions of the Irish government to introduce mandatory warning labels on which a direct link between alcohol consumption and cancer is pointed out shows that the proposed regulatory measures are already being applied [46,47]. In Germany, discussions include raising the minimum consumption age from 16 to 18. The connection between alcohol consumption and cancer is also part of scientific communication, as in the context of the *Alcohol Atlas* published for the first time in 2017—a publication that is strongly oriented towards the previously published *Tobacco Atlas* [48].

4.2. Tradeoffs in Social Sustainability within the Field of Non-Alcoholic Wines

As the consumption of alcoholic beverages is linked to various negative social and economic consequences, both the WHO and the EU are actively pursuing measures to reduce alcohol consumption in the long term through comprehensive regulatory proposals. From a social sustainability perspective, the increasing consumption of non-alcoholic alternatives can be seen as beneficial when it comes to reducing the consumption of ethanol as a highly health-relevant component of alcoholic beverages.

However, the consumption shift towards non-alcoholic alternatives also carries numerous implications regarding their health impacts, as many of these products may contain ingredients with nutritional relevance. Of particular concern is the sugar content of non-alcoholic beverages such as soft drinks and juices. As the main trigger of obesity and its link to diabetes, the extensive consumption of sugar is of high relevance [49].

In the production of non-alcoholic wine, the removal of ethanol leads to a concentration of acidity, necessitating the addition of sugar to balance the flavor profile. With common sugar contents of 20 to around 60 g per liter, the products are still below the sugar content of soft drinks. Nevertheless, the production of non-alcoholic wines involves a tradeoff between the two health-relevant substances ethanol and sugar. As the latest WHO publications indicate, drinks in the low- and no-alcohol category are also gaining the organization’s attention concerning the accusation of possible “alibi marketing”. This refers to companies promoting their brands without explicitly advertising products containing alcohol or excessive sugar levels that they also manufacture [50].

Overall, the shift toward non-alcoholic alternatives has a positive effect on social sustainability by reducing alcohol consumption. However, future research should also consider the health implications of non-alcoholic beverages, particularly their sugar content, to ensure a comprehensive understanding of their impact.

5. Discussion

The aim of this review was to analyze sustainability-relevant aspects of the production and marketing of non-alcoholic wines in Germany. The few available publications primarily deal with ecological sustainability, mostly focusing on the production of alcohol-reduced wines [18,51]. As shown, the additional use of resources is highly relevant in the field of non-alcoholic wines due to the use of the dealcoholization techniques. Specifically, methods such as distillation and membrane techniques result in increased consumption of resources such as water and electricity, indicating a negative tradeoff between alcohol removal and additional inputs.

However, this ecological perspective alone may not provide a comprehensive understanding of sustainability. Therefore, it is essential to also consider economic and social

aspects to enable a holistic view of the sustainability effects associated with the production and marketing of non-alcoholic wine.

From an economic standpoint, the market of non-alcoholic wines is showing promising signs of growth, although still on a very small scale [6,29]. This represents a positive trend as it opens up new marketing opportunities for producers. However, there are questions about whether non-alcoholic wines can fully compensate for potential losses in the much larger market for alcoholic wines and sparkling wines in the long term.

An optimistic outlook emerges regarding the social implications of increasing consumption of non-alcoholic beverages, considering the manifold negative effects of ethanol consumption. These effects extend beyond physical health, as detailed in Section 4. Diseases of the cardiovascular system, the liver and the psyche are among the most important risks. Problems also arise in the social context, as in the areas of crime and domestic violence [2]. From a social perspective, the wine industry often highlights the perceived status of its product as a stimulant, emphasizing responsible consumption and the role of wine in enhancing the enjoyment of life [52,53]. In addition, the wine industry repeatedly cites the benefits of resveratrol, a compound mainly found in red wine. Resveratrol is part of the group of anthocyanins which may contribute positively to the health of the cardiovascular system [54]. However, according to WHO publications, the negative effects of ethanol as a cytotoxin always predominate. This is reinforced by the developments in European alcohol policy, which show that wine is not given a special status when it comes to the introduction of regulatory measures [43–45].

This aspect could play a significant role in the future development of the market for non-alcoholic wine, as the consumption of wine is expected to decrease further in the future [26]. Social aspects also play an important role, especially considering changing consumption patterns in younger generations, who represent potential future wine consumers. This population group thus holds a high relevance when it comes to the future marketing of non-alcoholic alternatives. In this respect, it becomes clear that the three sustainability dimensions are also interlinked.

For instance, it is questionable whether younger generations, who tend to be more concerned with sustainability issues, can be targeted with products that require significantly more resources to produce. Therefore, the connection between social and ecological aspects becomes evident. From an economic and social perspective, the increased emphasis of alcohol policy on non-alcoholic variants is noteworthy, as illustrated by the discussion on alibi marketing. In the long term, these developments could have a negative impact on the market for non-alcoholic wines.

The connection between economic and ecological aspects becomes particularly relevant when increased energy usage is linked with significant additional production costs, ultimately reflected in their pricing. The recent price hikes in the energy sector across Europe underscore the risks associated with such inputs, including price fluctuations and procurement challenges. In the broader context, the tradeoff between environmental and social aspects seems to stand out in particular. The reduction in negative externalities with a simultaneous negative impact in the area of resource use is highly relevant. From a long-term perspective, this tradeoff may be mitigated by further developments in the processes. The balancing act between sustainability-related gains and losses in the case of non-alcoholic wines is illustrated in Figure 2.

The illustration not only depicts the tradeoffs within the three dimensions but also between them. For instance, the economic balance indicates the relationship between the potential gains from the emergence of a new market and the losses from the decline of the traditional wine sector. Simultaneously, the ecological impact also has effects on the economic dimension by increasing production costs.

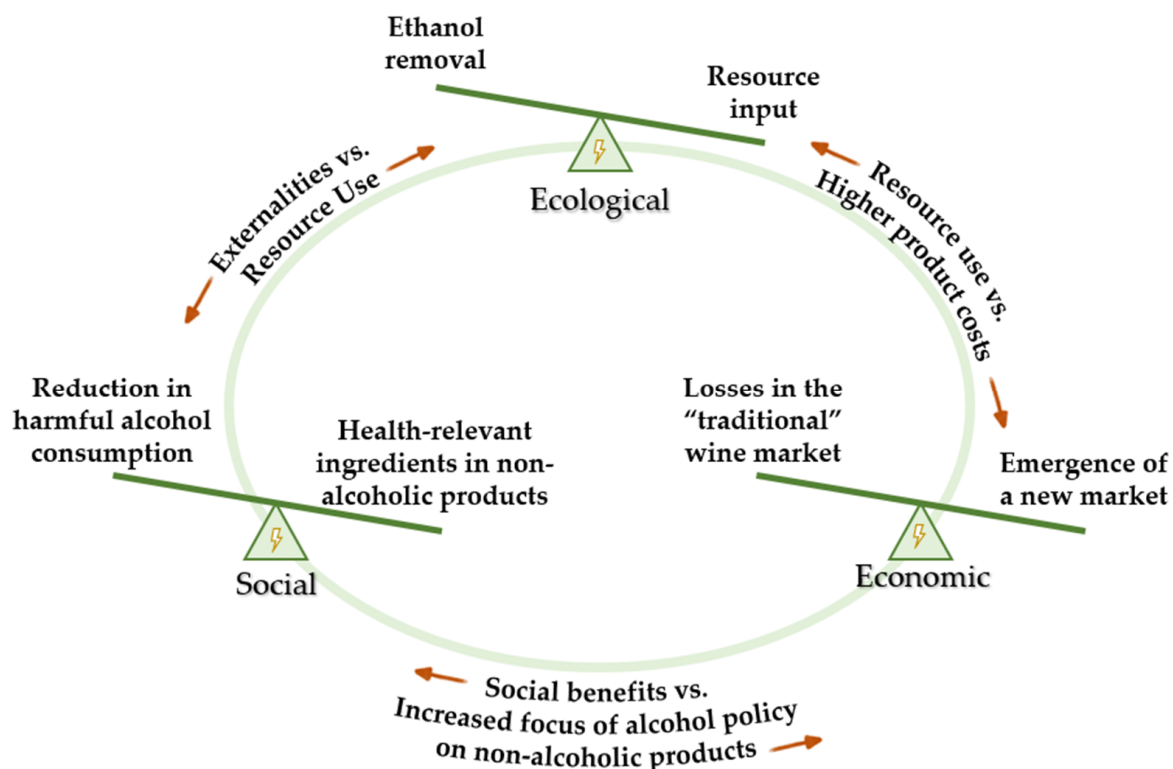


Figure 2. Balancing gains and losses in the case of non-alcoholic wines.

6. Summary and Outlook

The case of non-alcoholic wines demonstrates that, from the perspective of the three sustainability dimensions, the introduction, production and marketing of the products involve constant balancing. Initially, non-alcoholic wines are primarily characterized by the interplay between ecological and social aspects. However, the inclusion of economic considerations also reveals tensions. Table 1 summarizes the implications of sustainability tradeoffs of this review.

Ultimately, the relationship should not be interpreted as rigid, but is likely to evolve due to ongoing market developments. The findings collected in this review not only underscore the need for the further development of existing processes but also emphasize the importance of exploring alternative methods for producing non-alcoholic variants. For instance, novel fermentation processes, such as utilizing vine leaves, could offer a promising way to reach new target groups with innovative products.

The consideration of production and marketing of non-alcoholic wine from the perspective of holistic sustainability is still a largely unexplored field. Given the rapid political and social changes, this aspect has an increasingly important role, leaving much room for future research. As outlined in the introduction of this review, balancing win-win situations and tradeoffs is essential for evaluating sustainability impacts. Bringing both fields together offers a promising approach to better assess not only the future development of non-alcoholic wines but also the development of other non-alcoholic products, which are becoming increasingly important in a constantly changing market landscape.

Table 1. Summary of sustainability-relevant practices and tradeoffs in the field of non-alcoholic wines.

		Sustainability-Relevant Tradeoffs	
		To Gain	To Give Up
Sustainability-relevant practices	Steady increase in the production of non-alcoholic wines	<ul style="list-style-type: none"> • Response to the growing demand for non-alcoholic alternatives and the decline in wine consumption; • Emergence of a new market segment. 	<ul style="list-style-type: none"> • Risk of non-alcoholic alternatives not being able to compensate for losses in the traditional sector; • Risk of accusations of “alibi marketing” and subsequent regulatory measures.
	Usage of thermal and membrane dealcoholization processes	<ul style="list-style-type: none"> • Further developments of the processes lead to greater flexibility for producers; access to the market for small market participants; • Further developments of the processes lead to improved product characteristics; improving consumer acceptance. 	<ul style="list-style-type: none"> • Additional resource input in comparison to traditional winemaking; • Negative impact on the CO₂ footprint (thermal processes), high water usage (membrane processes); • Additional production costs; • Negative influence on the sensory characteristics.
	Removal of ethanol	<ul style="list-style-type: none"> • Contribution to the reduction in harmful alcohol consumption and reduction in negative externalities. 	<ul style="list-style-type: none"> • Necessary addition of sugar for sensory reasons (increase in other health-relevant ingredients); • Risk of accusations of “alibi marketing” and subsequent regulatory measures.

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References

1. OECD. *Tackling Harmful Alcohol Use: Economics and Public Health Policy*; OECD: Paris, France, 2015; ISBN 978-92-64-18106-9.
2. WHO. *Global Status Report on Alcohol and Health 2018*; World Health Organization: Geneva, Switzerland, 2019; ISBN 978-92-4-156563-9.
3. Schulz, F.N.; Richter, B.; Hanf, J.H. Current Developments in European Alcohol Policy: An Analysis of Possible Impacts on the German Wine Industry. *Beverages* **2022**, *8*, 75. [CrossRef]
4. Bundesverband der Deutschen Spirituosen-Industrie und -Importeure e. V. Daten aus der Alkoholwirtschaft 2023. Available online: https://www.spirituosen-verband.de/fileadmin/introduction/downloads/BSI-Datenbroschuere_2023.pdf (accessed on 2 February 2024).
5. Statista Consumer Market Insights. Pro-Kopf-Absatz von alkoholfreiem Bier in Deutschland in den Jahren 2014 bis 2023 mit einer Prognose bis 2027. Available online: <https://de.statista.com/statistik/daten/studie/1364658/umfrage/pro-kopf-absatz-von-alkoholfreiem-bier-in-deutschland/> (accessed on 2 February 2024).
6. Deutsches Weininstitut. Alkoholfreie Weine und Schaumweine. Available online: <https://www.deutscheweine.de/wissen/wein-mehr/entalkoholisierte-weine/> (accessed on 2 February 2024).
7. Bertram, J. Langlebiger Trend. *Wein + Markt* **2021**, *2*, 32–36.
8. Zamora, F. Dealcoholised Wines and Low-Alcohol Wines. In *Wine Safety, Consumer Preference, and Human Health*; Moreno-Arribas, M.V., Bartolomé Suáldea, B., Eds.; Springer International Publishing: Cham, Switzerland, 2016; pp. 163–182. ISBN 978-3-319-24512-6.
9. Byggeth, S.; Hochschorner, E. Handling trade-offs in Ecodesign tools for sustainable product development and procurement. *J. Clean. Prod.* **2006**, *14*, 1420–1430. [CrossRef]

10. Schmitt, M.; Christmann, M. Alcohol Reduction by Physical Methods. In *Advances in Grape and Wine Biotechnology*; Morata, A., Loira, I., Eds.; IntechOpen: London, UK, 2019; ISBN 978-1-78984-612-6.
11. Schmidtko, L.M.; Blackman, J.W.; Agboola, S.O. Production technologies for reduced alcoholic wines. *J. Food Sci.* **2012**, *77*, 25–41. [[CrossRef](#)] [[PubMed](#)]
12. Schmitt, M.; Christmann, M. Dealcoholization of white wines. In *White Wine Technology*; Morata, A., Ed.; Elsevier: Amsterdam, The Netherlands, 2022; pp. 369–377. ISBN 9780128234976.
13. Schmitt, M.; Freund, M.; Schuessler, C.; Rahuhut, D.; Brezina, S. Strategies for the sensorial optimization of alcohol-free wines. In Proceedings of the BIO Web of Conferences, 43rd World Congress of Vine and Wine, Ensenada, Mexico, 31 October–4 November 2022.
14. Varela, C.; Dry, P.R.; Kutyna, D.R.; Francis, I.L.; Henschke, P.A.; Curtin, C.D.; Chambers, P.J. Strategies for reducing alcohol concentration in wine. *Aust. J. Grape Wine Res.* **2015**, *21*, 670–679. [[CrossRef](#)]
15. Contreras, A.; Hidalgo, C.; Henschke, P.A.; Chambers, P.J.; Curtin, C.; Varela, C. Evaluation of non-Saccharomyces yeasts for the reduction of alcohol content in wine. *Appl. Environ. Microbiol.* **2014**, *80*, 1670–1678. [[CrossRef](#)] [[PubMed](#)]
16. Gonzalez, R.; Quirós, M.; Morales, P. Yeast respiration of sugars by non-Saccharomyces yeast species: A promising and barely explored approach to lowering alcohol content of wines. *Trends Food Sci. Technol.* **2013**, *29*, 55–61. [[CrossRef](#)]
17. Morales, P.; Rojas, V.; Quirós, M.; Gonzalez, R. The impact of oxygen on the final alcohol content of wine fermented by a mixed starter culture. *Appl. Microbiol. Biotechnol.* **2015**, *99*, 3993–4003. [[CrossRef](#)]
18. Margallo, M.; Aldaco, R.; Barceló, A.; Diban, N.; Ortiz, I.; Irabien, A. Life cycle assessment of technologies for partial dealcoholisation of wines. *Sustain. Prod. Consum.* **2015**, *2*, 29–39. [[CrossRef](#)]
19. Schmidt, O. *Moderne Kellertechnik: Neue und Bewährte Verfahren*; 13 Tabellen; Ulmer: Stuttgart, Germany, 2013; ISBN 978-3-8001-5681-8.
20. Hamatschek, J. *Technologie des Weines*; Ulmer: Stuttgart, Germany, 2015; ISBN 978-3-8001-7959-6.
21. Esteras-Saz, J.; de La Iglesia, Ó.; Peña, C.; Escudero, A.; Téllez, C.; Coronas, J. Theoretical and practical approach to the dealcoholization of water-ethanol mixtures and red wine by osmotic distillation. *Sep. Purif. Technol.* **2021**, *270*, 118793. [[CrossRef](#)]
22. Basile, A.; Galiano, F.; Santoro, S.; Figoli, A. Pervaporation and Membrane Contactors. In *Membrane Reactor Engineering*; Basile, A., de Falco, M., Centi, G., Iaquaniello, G., Eds.; Wiley: Hoboken, NJ, USA, 2016; pp. 280–312. ISBN 9781118906804.
23. Vilela, A.; Pinto, T. Grape Infusions: The Flavor of Grapes and Health-Promoting Compounds in Your Tea Cup. *Beverages* **2019**, *5*, 48. [[CrossRef](#)]
24. Fernandes, B.; Correia, A.C.; Cosme, F.; Nunes, F.M.; Jordão, A.M. Volatile components of vine leaves from two Portuguese grape varieties (*Vitis vinifera* L.), Touriga Nacional and Tinta Roriz, analysed by solid-phase microextraction. *Nat. Prod. Res.* **2015**, *29*, 37–45. [[CrossRef](#)] [[PubMed](#)]
25. Deutsches Weininstitut. Deutscher Wein Statistik 2021/2022. Available online: https://www.deutscheweine.de/fileadmin/user_upload/Website/Service/Downloads/Statistik_2021-2022.pdf (accessed on 2 October 2023).
26. Del Rey, R.; Loose, S. State of the International Wine Markets in 2022: New market trends for wines require new strategies. *Wine Econ. Policy* **2023**, *12*, 3–18. [[CrossRef](#)]
27. Spode, H. *Die Macht der Trunkenheit: Kultur- und Sozialgeschichte des Alkohols in Deutschland*; Leske und Budrich: Opladen, Germany, 1993; ISBN 3810010340.
28. Hieronimi, H.H. Alkoholfreier Wein? Erfahrungen in Deutschland. In Proceedings of the 33rd World Congress of Vine and Wine [and] 9th General Assembly of the OIV, Tbilisi, Georgia, 20–25 June 2010; pp. 513–521.
29. IWSR. IWSR: Growth of No- and Low-Alcohol. Available online: <https://www.theiwsr.com/wp-content/uploads/IWSR-2022-No-and-Low-Alcohol-Press-Release.pdf> (accessed on 8 August 2023).
30. Keller, E.-M. Das neue Alkoholfrei. *Weinwirtschaft* **2022**, *13*, 26–30.
31. Dempfle, M. DWV-INFO NR. 86/2023 RECHT: VERBOT VON ENTALKOHOLISIERTEM BIOWEIN KOMMT. Available online: <https://deutscher-weinbauverband.de/dwv-info-nr-86-2023-recht-verbot-von-entalkoholisiertem-biowein-kommt/> (accessed on 31 October 2023).
32. WHO. Global Information System on Alcohol and Health. Available online: <https://www.who.int/data/gho/data/themes/global-information-system-on-alcohol-and-health> (accessed on 3 February 2024).
33. Testino, G.; Leone, S.; Borro, P. Alcohol and hepatocellular carcinoma: A review and a point of view. *World J. Gastroenterol.* **2014**, *20*, 15943–15954. [[CrossRef](#)] [[PubMed](#)]
34. Rehm, J.; Samokhvalov, A.V.; Shield, K.D. Global burden of alcoholic liver diseases. *J. Hepatol.* **2013**, *59*, 160–168. [[CrossRef](#)] [[PubMed](#)]
35. Rehm, J.; Shield, K.D.; Weiderpass, E. Alcohol consumption. A leading risk factor for cancer. *Chem. Biol. Interact.* **2020**, *331*, 109280. [[CrossRef](#)]
36. Sontate, K.V.; Rahim Kamaluddin, M.; Naina Mohamed, I.; Mohamed, R.M.P.; Shaikh, M.F.; Kamal, H.; Kumar, J. Alcohol, Aggression, and Violence: From Public Health to Neuroscience. *Front. Psychol.* **2021**, *12*, 699726. [[CrossRef](#)]
37. Papalimperi, A.; Athanaselis, S.; Mina, A.; Papoutsis, I.; Spiliopoulou, C.; Papadodima, S. Incidence of fatalities of road traffic accidents associated with alcohol consumption and the use of psychoactive drugs: A 7-year survey (2011–2017). *Exp. Ther. Med.* **2019**, *18*, 2299–2306. [[CrossRef](#)]

38. Stuckler, D.; Mckee, M.; Ebrahim, S.; Basu, S. Manufacturing epidemics: The role of global producers in increased consumption of unhealthy commodities including processed foods, alcohol, and tobacco. *PLoS Med.* **2012**, *9*, e1001235. [CrossRef]
39. WHO. *Thirty-Sixth World Health Assembly: Resolutions and Decisions Annexes*; World Health Organization: Geneva, Switzerland, 1983; Available online: <https://apps.who.int/iris/handle/10665/159886?show=full> (accessed on 2 February 2024).
40. WHO. *Global Strategy to Reduce the Harmful Use of Alcohol*; World Health Organization: Geneva, Switzerland, 2010; ISBN 978-92-4-159993 1.
41. WHO. Seventy-fifth World Health Assembly—Daily Update: 27 May 2022. Available online: <https://www.who.int/news/item/27-05-2022-seventy-fifth-world-health-assembly---daily-update--27-may-2022> (accessed on 4 February 2024).
42. WHO. Tackling NCD's: 'Best buys' and Other Recommended Interventions for the Prevention and Control of Noncommunicable Diseases. Available online: <https://apps.who.int/iris/bitstream/handle/10665/259232/WHO-NMH-NVI-17.9-eng.pdf> (accessed on 5 February 2024).
43. European Parliament. Outcome, Work and Activities of the Special Committee on Beating Cancer: September 2020–December 2021—An Overview. Available online: https://www.europarl.europa.eu/cmsdata/246543/BECA_Compendium_final_lr.pdf (accessed on 3 February 2024).
44. European Parliament. REPORT on Strengthening Europe in the Fight against Cancer—Towards a Comprehensive and Coordinated Strategy: Amendments 033-037. Available online: https://www.europarl.europa.eu/doceo/document/A-9-2022-0001-AM-033-037_EN.pdf (accessed on 4 February 2024).
45. European Parliament. Strengthening Europe in the Fight against Cancer: European Parliament Resolution of 16 February 2022 on Strengthening Europe in the Fight against Cancer—Towards a Comprehensive and Coordinated Strategy (2020/2267(INI)). Available online: https://www.europarl.europa.eu/doceo/document/TA-9-2022-0038_EN.pdf (accessed on 27 January 2024).
46. Smith, C. 'Absurd' Health Warning Wine Labels in Ireland Angers Europe. Available online: <https://www.thedrinksbusiness.com/2023/02/absurd-health-warning-wine-labels-in-ireland-angers-europe/> (accessed on 12 April 2023).
47. Mercer, C. Tension Rises over Ireland's Health Warning Labels for Wine. Available online: <https://www.decanter.com/wine-news/tension-rises-over-irelands-health-warning-labels-for-wine-498570/> (accessed on 12 April 2023).
48. Schaller, K.; Kahnert, S. *Alkoholatlas Deutschland 2017*; 1. Auflage; Pabst Science Publishers: Lengerich, Westf, 2017; ISBN 978-3-95853-334-9.
49. Malik, V.S.; Popkin, B.M.; Bray, G.A.; Després, J.-P.; Willett, W.C.; Hu, F.B. Sugar-sweetened beverages and risk of metabolic syndrome and type 2 diabetes: A meta-analysis. *Diabetes Care* **2010**, *33*, 2477–2483. [CrossRef]
50. Schulz, F.N.; Farid, H.; Hanf, J.H. The Lower the Better? Discussion on Non-Alcoholic Wine and Its Marketing. *Dietetics* **2023**, *2*, 278–288. [CrossRef]
51. Aldaco, R.; Diban, N.; Margallo, M.; Barceló, A.; Ortiz, I.; Irabien, A. Environmental Sustainability Assessment of an Innovative Process for partial Dealcoholization of Wines. In Proceedings of the 9th International Conference on Life Cycle Assessment in the Agri-Food Sector, San Francisco, CA, USA, 8–10 October 2014.
52. OIV. Congress 'Lifestyle, Diet, Wine & Health'. Available online: <https://www.oiv.int/press/congress-lifestyle-diet-wine-health> (accessed on 2 February 2024).
53. Schulz, F.N.; Hanf, J. (Selbst-)Regulierung: Die deutsche Weinbranche im Zeichen neuer alkoholpolitischer Bestrebungen. In *Deutsches Weinbaujahrbuch 2024*; Stoll, M., Schultz, H.-R., Eds.; Ulmer: Stuttgart, Germany, 2023; pp. 110–117. ISBN 978-3-8186-2037-0.
54. Haunschild, R.; Marx, W. On Health Effects of Resveratrol in Wine. *Int. J. Environ. Res. Public Health* **2022**, *19*, 3110. [CrossRef]

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